The Development of Leadership among Chemistry Teachers in Israel

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Abstract

The implementation of new content and pedagogical standards in science education in Israel as well as in other countries necessitates intensive, life-long professional development of science teachers. Here we describe a model for the professional development of chemistry teacher-leaders. In the first part of the paper, we describe a model for the development and change of chemistry teacher-leaders. In the second part of the paper, we present the assessment of teachers' change. It is suggested, that in order to become a leader, the teacher has to undergo several interrelated phases of development and changes, namely personal, professional, and social. In order to attain these changes, a two-year program was designed in which teachers were given opportunities to develop their content knowledge, pedagogical content knowledge, and their leadership abilities and skills. The assessment of teachers' professional development clearly showed that engaging teachers in a long-term professional development program changed their beliefs (*personal* change) regarding their role as chemistry teachers in general and their confidence to become leaders in particular. In addition, we observed that the teachers changed in their *professional* abilities as well as in their *social* behavior. We also report on the involvement of the teacher-leaders in activities in which leadership skills were implemented in attempting to reform chemistry education in Israel.

General Introduction

New standards in science and mathematics education are being advocated, standards which reflect the current vision of the content, classroom environment, teaching methods, and support necessary to provide a high quality education in the sciences for all students (National Research Council (NRC), 1996; Bybee, 1995; Radford, 1998).

In the past, conventional methods of conducting pre-service and in-service education and professional development have not always proved to be adequate for attaining such demanding goals. In-service workshops conducted all over the world have been usually too short and occasional to foster a change in teachers' classroom practice (Loucks-Horsley, Hewson, Love, & Stiles, 1998). Unfortunately, many in-service projects were arranged as a one-time event with a very short lifetime (Van den Berg, Lunetta & Finegold, 1995). In contrast, the current reform is characterized by the attention given to the professionalization of science teachers (Loucks-Horsley & Matsomoto, 1999). Teaching science effectively in the classroom requires much more than just a straightforward implementation of the curriculum. One of the most promising and effective methods to attain the goals of reform and to enhance professional development is to develop leadership among science teachers (Bybee, 1993; Loucks-Horsley et al. 1998; Pellicer & Anderson, 2001; Hofstein & Even, 2001; Pratt, 2001).

Characteristics of Leadership in Science Education

In order to meet the challenges of reform in science education we need to help schools and other educational institutions, that are involved this reform, to meet the challenges of the times. One of the ways to attain these goals is to treat teachers as equal partners in decision making. In other words, teachers have to play a greater role in providing key leadership at all levels of the educational system (Pellicer & Anderson, 2001).

Leadership in the context of education was defined by Fullan (1991) as the ability of a person to bring about changes among teachers and teaching. Pellicer & Anderson (2001) define *"instructional leadership"* "as initiating, implementing and sustaining planned change in school's instructional programs, which is supported by the various constituencies in the school, and that results in substantial and sustained improvement in student learning" (p.9). Bybee (1993) adopted a leadership model for science education, originally developed by Locke (1991). This model defined the leaders' personal qualities, namely motivation, integrity, self-confidence, responsibility, creativity, and adaptability. Under the heading of skills that leaders in science education should acquire, he included knowledge of educational systems, science and technology, reform initiatives, curriculum, instruction, assessment, implementation, and staff development. Similarly, Pratt (2001) cited a report produced at NRC by Druckman, Singer &Van Cott (1997) suggesting that the research revealed that there are four basic skills relevant to effective leaders, namely (1) technical skills, (2) conceptual skills, (3) interpersonal skills, and (4) self-learning skills. It is suggested that this list is somewhat aligned with the model of professional development that was proposed and implemented for the professional development of science teachers by Bell & Gilbert (1994), which was adopted for use in the current study. This model consists of three dimensions, namely the development of teachers *personally, professionally,* and *socially*. This model was adopted for use in the professional development of mathematics teacher-leaders in Israel by Even (1999) (see also Hofstein & Even, 2001). *Personal* development in the context of the development of leadership among science teachers refers to the affective development that involves attending to feelings about the change process, about being a teacher, being a leader, and about science education. *Professional* development involves among other components, the use of different teaching skills in order to change those concepts and beliefs connected with the skills associated with teaching science (in our case chemistry). Thus, teaching chemistry in the capacity of teachers' development *professionally* includes both content knowledge as well as pedagogical content knowledge. The third component of the Bell & Gilberts' (1994) model, is the *social* dimension. This dimension involves learning to work with other people in the educational system in new ways. According to Bell & Gilbert (1994) these three dimensions are interrelated and the development of one aspect cannot proceed unless the other aspects also proceed. It is suggested the development in these three dimensions is vital for the development of leadership among teachers.

To sum up, it is clear that the development of leadership is a very demanding and complex process requiring a change in all aspects of intellectual activity. More specifically, according to Friel & Bright (1997), it requires explicit attention, clear expectations, and resources (time and expertise).

Our main goal for this manuscript is to present and discuss the educational effectiveness of a model for the development of chemistry teacher-leaders and to assess the teachers' change process. It should be noted that this study is more descriptive rather than analytical in its nature.

The Context of the Study

In this paper, we describe an innovative program developed in Israel, whose aim is to improve the pedagogy of chemistry education in the educational system. It focuses on a model aimed at the professional development of chemistry teacher-leaders. According to the plan these teacher-leaders will eventually serve as agents for change in bringing about reform in chemistry education. This initiative was part of a more comprehensive reform conducted in Israel in science, technology, and mathematics education in the last 10 years (Tomorrow 98, 1992).

Israel has a centralized education system. The syllabi and curricula are regulated by the Ministry of Education. Since the 1960s', the Ministry of Education has provided for the long-term, dynamic development of science curricula and its implementation. These initiatives were usually accompanied by short courses (summer school) for science teachers, intended to introduce them to the new approach and its related scientific background. These courses were usually conducted at science teaching centers located in several academic institutions throughout the country as part of the Israeli Science Teaching Center, the central consortium of science curricula development and implementation.

In 1992 the 'Tomorrow 98' (1992) report on reform in science, technology, and mathematics education was released. The report includes 43 recommendations for special projects, changes, and improvements, both educational and structural, in the area of curriculum development and implementation, pedagogy of science and mathematics, as well as directions and actions to be taken in the professional development of science and mathematics teachers in general, and the development of leadership among teachers in particular.

More specifically, the report recommends:

- Providing science teachers with the opportunity to engage in life-long learning.
- Creating an environment of collegiality and collaboration among teachers who teach the same or related subjects, an environment that encourages reflection on their work in the classroom.
- Incorporating the process of change into professional development (support for these goals can be found in Loucks-Horsley, Hewson, Love, & Stiles, 1998; Tobin, Tippins & Gallard, 1994).

In order to attain these goals, national and regional centers for the professional development of science and mathematics teachers were established (for more details, see Hofstein & Even, 2001). The overriding aim of these centers is to encourage educational reform by providing a strong framework for the development of teachers. These national centers are, among other activities, responsible for the development of science teacher-leaders who are expected to initiate, plan, and implement long-term professional initiatives in both their schools as well as in professional development regional centers around the country.

Description of the Leadership Program

A program aimed at developing leadership among chemistry teachers was initiated at the *National Center for Chemistry Teachers* located at the Weizmann Institute of Science. The program was planned with the assumption, that the participants are thoughtful learners; that they are prepared to be professional teacher-leaders; that after completion of the program the teachers will develop their own ways and strategies for initiating reform in the way chemistry is taught, and in professionalizing other chemistry teachers. Consequently, it was decided to design the program around the following three components:

- Developing the teachers' understanding about the current trends of chemistry teaching and learning to include both the content and pedagogy of chemistry learning and teaching;
- Providing the teachers with opportunities to develop *personally, professionally,* and *socially.*
- Developing leadership and the ability to work with other chemistry teachers.

Participants

The leadership program consisted of 19 chemistry teachers who were considered to have the potential to become teacher-leaders. These teachers were reported by their headmasters, regional tutors, and peers to be highly motivated to bring about changes in the way chemistry is taught in their schools, to be creative in the way they implemented chemistry curricula in general, and innovative instructional techniques in particular.

More specifically, they:

- Were chemistry coordinators in their respective schools with reputations of being good teachers and good chemistry coordinators;
- Had at least 10 years of experience in teaching high school

chemistry (10-12th grade), including experience in preparing students for matriculation examinations (final examination centrally set by the Ministry of Education);

- Had at least the 1st degree in chemistry (B.Sc.); 10 teachers had even higher academic degrees (M.Sc. or Ph.D.).
- Had participated in many in-service professional activities,
- Agreed to a two-year commitment to participate in an intensive leadership program that took place once a week over a period of two years;
- Were released from their schools for one day a week, and received some honorarium regarding their salary.

Our assumption was that these teachers possessed at least partially, the expected personal characteristics of a teacher-leader, as described by Bybee (1993) and others that include motivation, self-confidence, creativity, integrity, responsibility, and charisma.

The content of the leadership program

The program extended over a period of two academic years (1997-1999), totally 450 hours, conducted one day a week. The program extended over a two-year period in an effort to allow for the gradual development and growth of the participants' conceptions, beliefs, and changes in behavior. In other words, to allow enough time for the development of teachers *personally, professionally,* and *socially* (Gilbert & Bell, 1994). The first year of the program was mainly devoted to the development of the teachers' content knowledge and pedagogical content knowledge, whereas the second year was mainly devoted to the development of skills in the area of leadership. The various abilities and skills were developed using many of the strategies for professional development suggested by Loucks-Horsley et al. (1998). (For more details see Figure 1).

The First Year of the Program

The first year (first stage) of the program was mainly devoted to the development of the participating teacher's *content knowledge* and *pedagogical content-knowledge*. These include among other thing knowledge of concepts in chemistry, instruction, assessment, students' learning and concept formation, and issues of implementation in programs with different student populations and serving different students' interests. The issue of chemistry teacher-leader's knowledge of chemistry is critical since in recent years, science educators in general and chemistry educators in particular have realized that science is taught not only to prepare students for an academic career in chemistry, but also to become informed citizens in society. Our society is highly influenced by scientific advances and its accompanying technological ramifications. Consequently, chemistry, for example, should be taught with appropriate emphasis on its relevance to everyday life and its role in industry, technology, and society. In recent years, the chemistry curriculum has changed dramatically, from focusing on the structure of the discipline approach to a multidimensional approach. Even in 1983, Kempa claimed that the future development of teaching and learning materials in chemistry should include the following dimensions: the conceptual structure of chemistry, the processes of chemistry, the technological manifestations of chemistry, chemistry as a 'personally relevant' subject, the cultural aspects of chemistry and finally, the societal implications of chemistry. More specifically, it is suggested that in the teaching and learning of chemistry, students should be exposed to recent investigations, namely the “frontiers of chemistry”. Moreover, chemistry should be viewed as an inquiry-based discipline, giving rise to new knowledge and insights. To this end, problems could be solved both in the classroom as well as in the laboratory, using inquiry-type activities and methods. This approach enables the students to ask questions, plan and conduct investigations, think critically, construct and analyze alternative explanations, as well as express scientific arguments (Bybee, 1997). In addition, in order to make chemistry more relevant to the students’ lives and to the society in which they live, chemistry should be taught as an applied science of major economic and technological importance.

This approach to high school chemistry makes a great demand on the chemistry teachers. Traditionally, most of the teachers, both in their pre-service training as well as in most of their in-service experience, are exposed to only the first two components, namely the conceptual structure and the processes of chemistry. The other components, presenting the technological application of chemistry, its influence on society, and its cultural characteristics were usually neglected or received only limited attention.

In view of these developments we selected several chemistry topics that represented the frontiers of chemistry and that we believed were relevant and interesting. Among these topics are *‘radioactivity* and *radiation’, ‘the chemistry of nutrition’, ‘material science’, ‘semiconductors’, and ‘chemistry of the brain’*. Note that although the Chemistry syllabus in Israel is regulated by the Ministry of Education, teachers have some freedom to add and implement topics that are not part of the syllabus. They also have some freedom to use alternative assessment methods aimed at assessing students’ achievement and progress in these areas.

The aim of the *content knowledge* dimension of the program was to enhance the chemistry teachers' knowledge of the various chemistry topics mentioned. This was accomplished by providing the teachers with a series of lectures on these topics and workshops conducted by the Weizmann Institute scientists, visits to research laboratories, and by conducting intensive workshops with scientists (see Figure 1).

(Insert Figure 1 about here)

We chose to exemplify the structure of the first stage of the professional development by using the topic that deals with the concept of '*radiation and radioactivity'*. This topic is very much interdisciplinary in nature, including the scientific concepts (e.g. the various types of radiation), the technological manifestations and societal implications (e.g. use of such radiation in medicine, and the environmental and personal issue of using such radiation). The topic also has distinctive historical components; thus it can be used as a good example for demonstrating to students the nature of science and the scientific endeavor. A similar approach was used to develop the teachers' knowledge regarding other topics previously mentioned.

Following this stage (in which teachers enhanced their knowledge of the various topics), they were asked to think of ways and strategies of adapting these topics to their own students, i.e. translating the knowledge they encountered into actual teaching and learning practice. During this stage, while working in groups, the teachers were asked to plan different approaches and to modify the subject matter to meet the different abilities, needs, and interests of the students. For example, for students specializing in biology, the teachers developed the topic of using radioactivity in medical diagnosis. For those who had studied "Science for All", an interdisciplinary approach was adopted to teach the topics. The 'Science for all' approach uses the STS philosophy, including the science concepts (e.g., radioactive particles), technological ramifications (e.g., the use of radioactive radiation to sterilize potatoes and onions), and societal applications (e.g. the hazardous nature of radiation and other related environmental issues). The participating teachers developed worksheets, gathered background materials, and identified sources of information on the web. This was done with regard to students' conceptions and misconceptions as they appeared in the literature. For example, the teachers discussed the use of appropriate models to bridge the gap between the macroscopic and microscopic nature of the phenomenon and the concepts taught. They suggested models, computer simulations, and analogies to make the topic more accessible to individual students. Different groups presented various developments and pedagogical suggestions to the whole group and to the program tutors. Following their presentations there were discussions and deliberations regarding the merit of the materials, and its feasibility for classroom implementation. These activities could be regarded as the stage at which teachers had an opportunity to enhance their pedagogical content knowledge (PCK) (Shulman, 1986; Gess-Newsam, 1999). As already mentioned, the present era is characterized by not only new standards regarding the content of science, but also by the way science is taught.

The ability to design and implement varied types of instructional techniques and their related assessment tools in order to align these techniques with students' different cognitive abilities and learning styles is seen as an important component for the development of leadership (Hofstein & Kempa, 1985; Doyle, 1985; Gitumer & Duschl, 1998; Darling-Hammond, 2000).

The second phase of the program: second year.

During this phase of the program, the participating teachers were involved in special workshops guided by professional experts, for developing their decision-making and management ability (communication and cooperation), for resolving conflicts, solving interpersonal group problems, building and communicating visions, and for developing social understanding and skills. For example, a specialist in organizational psychology conducted a workshop that included activities aimed at team building and management. The teachers were involved in role-playing and simulation of situations in which a teacher-leader was working with his/her team in school, with school management, and teacher-leaders in other science subjects (biology or physics). These include issues such as the adaptation of new units, instructional techniques, and other organizational issues regarding the teaching and learning of science in general, and chemistry in particular. The participating teachers were asked to organize teams of chemistry teachers in their own schools for whom they would be responsible in providing leadership. More specifically, with this strategy in mind, the participating teachers coached their peers in teaching the subject matter created during the professional development program. In addition, they helped them improve their teaching by introducing a variety of activities and by providing them with feedback regarding their classroom teaching.

The atmosphere of collegiality and support that developed among the participating teacher-leaders throughout the program helped the teachers ‘to digest’ and cope with critical and negative information, and to make the necessary changes or to introduce appropriate remedies needed for overcoming the learning difficulties that occurred. With the help, guidance, and support of the program instructors and their peers, the teacher-leaders were given opportunities to reflect on their fieldwork and thus obtained feedback for the purpose of further development and improvements. This again was conducted by the ‘open-platform’ mentioned above that was created in the program in order to deal with problems that emerged in the teachers’ daily work in their schools, both in their own classrooms as well as with the team of chemistry teachers. This ‘open-platform’ supported the development of an environment that enabled the teachers to share ideas, critically evaluate new notions, openly discuss new concepts and reach conclusions that eventually led to their ability to make valid and effective decisions and to take responsibility.

Assessment of teachers’ changes resulting from the leadership program

Research objectives and questions

The assessment of the development of leadership among the chemistry teachers focused on three interrelated variables, namely:

- Development of their *personal* beliefs about themselves, about teaching chemistry, and about becoming a leader;
- Development of their *professional* behavior and activities in their

chemistry classroom;

- Development of leadership skills, and activities with other chemistry teachers in and outside their schools (social development).

More specifically, the study focused on the following research questions:

1. Was there any observable change in the participating teachers' personal beliefs regarding the impact of the leadership program on their practice as teachers and teacher-leaders?

2. Were there indications, as a result of the teachers' leadership program, that there was an observable change in the teachers' activities in their classes (*professional* change)?

3. As a result of experiencing the program, was there evidence that the teachers initiated and conducted activities in which leadership abilities were needed in their schools as well as in regional centers where professional experiences for chemistry teachers are provided?

Throughout the program, and a year after the teachers' graduation, the teachers (N=19) were assessed continuously in an attempt to obtain answers to these questions. In order to increase the validity of the assessment we used the triangulation method namely a combination of both qualitative and quantitative strategies and tools. The teachers' changes and development were assessed over a period of two academic years (1996-1998).

Assessment tools

Changes in the teachers' personal beliefs

1. For the purpose of obtaining information about the teachers' personal perceptions and beliefs, professional attitudes, the relationship with peers in school and their classroom practice, a questionnaire titled "feedback questionnaire" was developed. In this questionnaire, teachers were asked to rank the items on a likert-type scale in which 1, denoted total disagreement and 7, total agreement. It was administered twice, at the end of the 1st year of the program and again in its end. The initial questionnaire consisted of 17 items. Five items were deleted due to relatively high value of standard deviation. The 12 items that were retained, means and standard deviation for each of the items and F-test to compare the means, and the professional development category for each of the item are presented in Table 1. The decision to use a self-report questionnaire was based on the literature (recently reviewed by Lawrentz, 2001) claiming that such instruments could be regarded as valid and reliable if they are administered and the data collected at times when almost person's immediate responses can be obtained. Mailing-in opinion surveys usually results in a low response rate and low validity. In this study the teachers were asked to respond to the items during the sessions of the leadership program. In other words, they were asked to do it spontaneously. Thus, we believe that they responded to the items with honesty. We managed to collect pre and post questionnaires from 14 (out of the 19) participating teachers (See Table 1).

(Insert Table 1 about here)

2. Information about the teacher' perceptions and beliefs were also obtained using in-depth, unstructured interviews (Fontana & Frey 1998). Such interviews were conducted with several teachers who participated in the program. The results of these interviews were analyzed using a combined method of first, generating categories (Strauss & Curbin, 1998) and then presenting these categories in displays or matrixes (Miles & Huberman, 1994). This techniques, enables the researcher to look for communalities and patterns regarding the participating teachers beliefs. Altogether throughout the course 20 interviews were conducted focusing on the teachers' beliefs, expectations, their behavior and actions in their schools and in out of school settings. In addition, the teachers were interviewed on their perceptions regarding the contributions of the program on different setting of their work. For the purpose of the final analysis we conducted a comparison of:

- Interviews of the teachers held in different times. This was conducted in order to examine changes and differences that might have occurred over time.
- Interviews held with different teachers during the same period of time. These were conducted in order to explore whether there are differences between the participating teachers in a certain point of the program timeline.

3. In addition, teachers were asked to freely express their opinion in an open-ended type questionnaire regarding their reasons for enrolling in and

their expectations from the leadership program. This questionnaire was administered several times throughout the program in order to assess changes continuously.

Changes in the teachers' behavior in their classroom.(research question 2)

The Learning Environment Inventory (LEI) was used to assess students' perceptions of the various components that comprise the classroom learning environment. Measures of the classroom learning environments have been clearly shown to be related to positive student outcomes and to be sensitive indicators of differences in classroom environments (Fraser, 1998). The use of classroom learning environment instruments was well documented in the literature (Fraser, 1998) and was found to be a reliable and valid measure that can replace actual classroom observations. In addition, such measures were found to be sensitive to different teaching and instructional techniques used in the classroom and to different teacher-students interactions. More recently, Lawrentz (2001) suggested the use of measures of classroom learning environment in order to assess changes in students' perceptions resulting from their teachers' involvement in professional development activities.

The Hebrew version of the instrument that was used consists of 7 scales and 50 items. We chose to use here only those scales that were highly related to the teacher's behavior in the classroom and their interaction with their students, e.g. satisfaction, goal-direction, and speed. The Learning Environment Inventory was validated in its Hebrew version in previous studies conducted in Israel (Hofstein & Lazarowitz, 1986). Table 2 presents the scales used in this study, sample items, and the value of the α Cronbach reliability coefficient for each of the scales.

(Insert Table 2 about here)

The LEI was administered to 11th grade students throughout the leadership program twice at the beginning and at the end. The measure was administered to the students of 10 participating teachers who had 11^{th} graders at the time of the assessment. The decision to administer the measure to 11^{th} grade students was made since this grade represents a year in which the teaching of chemistry is at its peak without interference from final examinations. In addition, 11^{th} grade is usually the year in which chemistry is taught with the maximum intention regarding instruction and pedagogy. Series of F-tests were used in order to compare the students' mean perceptions. The MANOVA (multiple-analysis of variance) procedure was used in order to get a comprehensive picture of the differences between the groups of students who were taught chemistry during two different periods regarding their teachers' professional experiences.

2. Information about the teachers' behavior and progress regarding their own classroom was also obtained through interviews that were held with a sample of about 8 teachers throughout the program. In addition, we also considered the items in the feedback questionnaire that are related to teachers' beliefs regarding their change in the *professional* domain. (see Table 1).

Assessment of teachers who are involved in leadership activities (Research question 3)

After the termination of the program, several teachers started to practice leadership either in regional professional development centers or as tutors of chemistry. In order to obtain information about their perceived role as teacher-leaders, and their actual functioning as leading-teachers, we combined both participated-observations (Adler & Adler, 1998) and interviews. The observer (who acted as a participating observer) collected data about the teachers' beliefs and behavior. The observations on teachers who were practicing leadership focused mainly on their behavior during the leadership program, the workshops that they conducted with teachers, and while they tutored chemistry teachers in the region.

For the purpose of this section we chose, to present a case study of one of the teacher-leaders that became a tutor and advisor in one of the regions in the country.

Results

Change in teachers' beliefs (research question 1)

In regard to the teachers' changes in beliefs, we found (based on the analysis of the open-ended questionnaire) that at the beginning of the program the teachers' expectations were relatively high and were mainly focused on the development of content knowledge and pedagogical content knowledge (80% of the participants). In addition, 34% of the participating teachers perceived that the goal of the program was to improve their capabilities to cooperate with their colleagues in school. Only 27% of the teachers perceived that the main goal of the program was to enhance their abilities to become future teacher-leaders in the field of chemistry education. The idea that they are expected in the future to provide leadership and to help in reforming chemistry education had not yet been internalized. At the end of the of the first year, the percentage of teachers that perceived the program goals as associated with leading and instructing other teachers had increased significantly. Finally, at the end of the program, most of the teachers (about 95%) found the program's objectives much clearer, and that they were ready to embark on a career in which providing was leadership required.

The following are some typical quotations from the teachers at the end of the program:

- *We were trained to lead chemistry at school.*
- *We must enhance the team of teachers at school.*
- *We are chemistry teachers who are ready participate in the educational field to make some changes.*

In order to further illustrate these changes which occurred over time, we opted to quote from an interview that was conducted with one of the participating teachers. This teacher was interviewed twice. In these interviews the central theme was her perception regarding the changes that she underwent, in becoming a teacher-leader.

At the end of the first year she said:

"I don't consider myself as someone capable of guiding other teachers… but I understand that we are expected to do so…"

At the end of the second year she said:

"Only now do I understand that I must undertake the responsibility of guiding other teachers in my field. It has become important for me to carry out this mission."

An important goal of the personal development aspect of the program was to help the teachers develop a professional sense and confidence. When entering the program, many did not consider themselves teacher-leaders. Often, they were not sure what their role really entailed.

At the beginning of the program, many felt that they do not have adequate skills or sufficient knowledge to lead other teachers. However, it was seen that gradually, through involvement in the program's activities, the participating teachers' self-esteem improved and they became more confident regarding their future role.

An analysis of these interviews clearly revealed a gradual development of the teachers' self-perception regarding their competence in the various aspects of the program in general, and in their ability to perform activities in which providing leadership is vital, in particular. The feedback questionnaire (see Table 1) was another source for information about the change in the teachers' perceptions regarding their feelings and beliefs about the change that they underwent. As shown in Table 1, in general, the values of the mean rating of the participating teachers' perceptions and beliefs increased from the first to the second year of the program.

It was found that in general, the mean rating for the first year was lower than the one for the second year. In six of the items the differences reached level of significance. These were mainly in the case of items that were categorized as *personal* development (items: 10, 11, 7 12) and items categorizes as professional (items: 5, 6, & 9). The significant changes between the end of the 1st year and the end of the 2nd year provides evidence that the participating teachers were more positive regarding the effects of the activities in the leadership program. In regard to items categorized as *social* development it is seen that the value of the means (items: 1, 2, 3, & 7) were already high at the end of the 1st year. Thus although some increase the mean value is visible it failed to reach level of significance. One can learn from these results that the teachers perceived that they were provided with opportunities to develop personally and professionally. In addition, they were involved in learning experiences that had potential to develop their social skills.

Teachers' behavior and activities in their classroom (research question 2)

As mentioned before, in order to probe into the teachers' changes in their behavior and activities in their own classroom, we used the Learning Environment Inventory (LEI). The mean, F-value, and level of significance for each of the scales are presented in Table 3.

(Insert Table 3 about here)

As shown in Table 3, in general, the perceived learning environment was significantly improved during the period that elapsed between the 1st and the 2nd time that the instrument was administered. More specifically, one should note the positive and significant change in the scales that assess students' perceptions specifically: 'goal direction', 'satisfaction', and 'speed'. These scales are highly related to the teachers' behavior in the classroom and the way they teach (in this case chemistry). Multiple-analysis of variance (MANOVA) which was conducted in order to obtain a more comprehensive picture of the change in the students' perceptions of the chemistry classroom learning environment provided the following results: F= 7.4, P=0.0001, and (df =7, 370). This means that in general, there was a significant change in the classroom behavior of the teachers as perceived by their students. The only drawback regarding these findings is the fact that the instrument was administered among different students' cohorts but this is the only research approach one could adopt if one wants to assess the changes in the classroom learning environment with the same group of teachers and the same students' grade (11^{th} grade). Support for the findings that were revealed from the learning environment measures was obtained from the interviews conducted with a sample of the teachers. Based on the analysis of these interviews, the teachers' approach to various classroom activities was changed. For example, regarding students' projects, they reported that in the past the focus was on the end-product whereas currently the focus is primarily on the process in which the students are involved. One of the teachers reported that

> *Each year, in the 10^{th} grade, groups of students work on projects regarding metals and their related compounds. This year, as a result of my experience in the professional development program, it was quite different. First, I gave my students the assessment criteria regarding the project. I told them that they can earn extra points for creativity in addition to the scientific components of the project. As a result, students came with many new ideas and suggestions for further investigations.*

In addition, in regard to varying the classroom learning environment, teachers reported on the use of alternative instructional techniques and their related assessment tools. These were activities that they themselves had experienced in the leadership program. Also, teachers reported on their increased awareness regarding personal differences among students and more awareness regarding their learning difficulties and misconceptions. One of the teachers said:

> *"I have never carried out the diagnostic tests with such conviction as I did after this program. I was convinced about the importance of the issue".*

To sum up, the combination of the students' perceptions and the results of the interviews showed a significant change in the teachers' *professional* behavior.

Becoming a teacher-leader (research question 3)

At the end of the program, more than two-thirds of the teachers started to practice leadership in various establishments and institutions in which leadership in the area of chemistry education is needed. The opportunities to practice leadership were either in their own schools, where they could use their experiences to work with the team of chemistry teachers, in regional professional development centers, in which workshops for chemistry teachers are conducted, and as curriculum developers in which new content and pedagogical content standards are developed and implemented. Most of the information about the teacher-leaders' activities and behavior was gathered through observations about their practice in regional centers where they were tutoring and coaching other chemistry teachers as well as by interviews that were conducted frequently, especially with those who became regional tutors.

For the purpose of this manuscript, we decided to tell the story of one teacher-leader called Debbie. Debbie graduated from the program and became a regional tutor. In general, a regional chemistry tutor is a teacher who is nominated by the Ministry of Education to provide guidance and support for chemistry teachers in his/her region.

The qualitative information on Debbie was gathered via observations and interviews conducted by one of the authors of this manuscript, continuously over a period of three years.

Debbie's story : A case study

Debbie was a coordinating chemistry teacher in her school, with 16 years experience in teaching high school chemistry. She started the program with the feeling of satisfaction regarding her work in school and her interaction with her students. In addition, she was highly appreciated among school management as well as among her colleagues in school. Debbie was interviewed continuously throughout the program and a year after the program's termination. In an interview conducted at the beginning of the program she claimed that she was ready for a change since it was clear to her that she needed more experience regarding the content and pedagogy of high school chemistry. Her expectations from the program were fairly high and she had a clear notion regarding the program's goals. Upon entering the program, her expectations from the program were highly focused on improving her professional abilities as a teacher and as a school chemistry coordinator. When interviewed at the beginning she said:

> *"I expect to be updated in chemistry regarding the curriculum. I hope to experience new teaching strategies, especially*

regarding students' projects and the assessment of students' progress".

Throughout the program, she was very prominent in her contributions in general, and in the debates and discussions with the group of teachers with whom she worked, in particular. She was very open-minded regarding her involvement in the development and implementation of new instructional techniques and its aligned assessment methods. Very often she reported to the program participants on the experiences in her class in which she tried to implement the various instructional techniques and other pedagogical ideas that she employed. It was clear, that these ideas were highly based on her experiences in the program.

At the end of the 1st year she claimed that the most profound contribution of the program was an increased awareness of the differences among students, an acquaintance with new instructional techniques and their related assessment methods, employment of action research in ones own classroom, and working closely with other teachers.

These comments indicate that the program gave her opportunities to develop *personally*, *professionally,* and *socially*.

More specifically, she said:

> *"For me, to succeed in the program means to implement in my school the ideas to which I was exposed in the program".*

In an interview conducted at a later stage she said:

> *"I have done in school what we have done in the program. I have transferred the methods and strategies from our program to our school".*

During the 2nd year of the program, Debbie admitted that tutoring and coaching other teachers meant a lot to her and gradually became convinced that a she could embark on a career where she could offer her professional experience to other teachers.

When she was interviewed at the end of the program she said:

> *"The program equipped me with skills to lead other teachers and to promote a change process. I am already doing it in my own school and I hope that I will able to develop my self beyond my school boundaries."*

After graduating from the program, Debbie was promoted to become the head of the science department in her school In this capacity, she became involved in the guidance of all the science teachers in her school referring to different programs, such as Science for All, (STS-type programs), biology, chemistry, and physics. A year later, she became a regional tutor.

We observed her work as a tutor, and realized that again she employed similar strategies to those that she had experienced in the program, for example, working collaboratively in small groups, reflecting on one's experiences, and creating an atmosphere of support and collegiality.

To sum-up, it is clear that Debbie's professional development through the leadership program combined with her work in school as a chemistry teacher and head of the science department, gave her the skills to guide other teachers and thus to become a full-fledged chemistry teacher-leader.

Discussion

We are operating in an era of extensive reforms in science education. This present reform, compared to previous reforms is standard-based and…. "Very often is referred to as "systemic" because all parts of the system are coordinated so that they are all addressing the same major goals and program outcomes" (Pratt, 2001). There is no doubt that in order to attain these rather ambitious goals the science education milieu must seriously consider the professional development of leaders who are going to support the attainment of such a reform. In general, the literature is rich in theories regarding leadership in education but relatively limited regarding effective models that can be adapted in order to develop teacher-leaders for the purpose of reforming science education.

The program for chemistry teacher-leaders was designed to include all the necessary components that comprise the life-long professional development of science teachers, and also those components that are unique to the development of leadership among teachers. There is no doubt that strengthening the teachers' knowledge of chemistry and the pedagogical content knowledge of chemistry are prerequisites for becoming a leader. We have evidence that at the end of the program, the program's participants had grown *professionally, personally and socially*. Such growth could be detected in the participants' reports and feedback questionnaire and interviews that were conducted with a sample of the participants throughout the program. In addition, based on our observations, it was clear that the teachers developed useful social skills and habits. These were developed through small group collaborative discussions and debates on issues regarding students' learning ideas relating to the teaching of chemistry as well as the professional development of other chemistry teachers (ideas about planning and conducting chemistry workshops and courses).

Based on our assessment (interviews and open-ended questionnaires administered throughout the course), it was found that in entering the program, most of teachers did not consider them selves as leaders rather than school chemistry teachers who learn to become better teachers. Only gradually through enhancing their content knowledge and through the opportunities to develop their personal, professional, and social abilities they started to admit that they are ready to embark on duties that will involve them with activities in which leadership is required. In addition, we found that towards the end of the program, as a result of intensive guidance and involvement in professional development activities, there was a significant enhancement in the teachers' internalization of the main goals of the leadership program. These developments could not have occurred without the teachers being provided with experiences that aimed at enhancing their chemistry content and pedagogical content knowledge. During the program, the teachers were provided with numerous and varied types of opportunities to develop their chemistry knowledge, teaching and assessment skills, as well as general science education skills. In addition, they were given opportunities to plan and develop learning materials, instructional activities, and their aligned assessment methods and to implement them in their own chemistry classroom. During the program, using action research activities, the teachers had opportunities to assess the impact of the newly developed learning material on students' learning.

The results of the students' perceptions of the classroom learning environment revealed a significant improvement in several scales of the learning environment inventory. We believe, that the significant increase in students' perceptions in the scales of goal-direction and satisfaction and a decrease in speed and friction could be the result of the change in the teachers' activities and the *professional* behavior displayed in their chemistry classroom. It is also believed, that the changes and experiences that the teachers underwent during the program accounted, at least partially, for the positive change in the students' perceptions of their chemistry classroom-learning environment.

Support for the findings regarding changes in students' perceptions of the chemistry classroom-learning environment was revealed in the feedback questionnaires. In these questionnaires the teachers reported an increase in making chemistry more interesting for their students, in their improved ability to cope with students' learning difficulties (by using diagnostic tests, for example) and in varying the type of instructional techniques that they adapted for use in their classrooms. It is clear that the experiences that the teachers had in the program enhanced their confidence to try new ideas in their classroom and to better plan their activities. It is suggested that the combination of classroom learning environmental measures, in-depth interviews and a feedback questionnaire increased the validity of the findings regarding the teachers' behavior and the activities they employed in their classrooms.

The third component of professional development, based on Bell & Gilbert's 1994 model, is the social component. Social development involves learning to work with other people in the educational system in new ways. It is suggested that in order for teachers to develop socially they need to have a strong and solid professional foundation. This is the case since many of the activities that were used in order to enhance the teacher professionally involved the teacher working with others in the program and later on in their schools. The teachers were given opportunities to work with others in the program since most of the work was conducted cooperatively in small groups. In addition, in the second year the participating teachers started to coach and mentor the team of chemistry teachers in their school. From the feedback questionnaire administered to the participating teachers and on the basis of the interviews held throughout the program, the teachers reported an increased intensity of working with other teachers in their schools. These professional development strategies were similar or identical to those that were used in the leadership program.

It should also be mentioned that the program's participants were not the only learners during the two-year program. The program's staff learned how to conduct such a program for the development of teacher-leaders, what its focus, content and nature should be, and how to implement it. We are aware of the limitations of a study that is partially based on information gathered from teachers' reports. However, keeping this information in mind, since data was gathered several times throughout the year, the information should be considered relatively reliable and valid. It is suggested that in order to better understand the processes and educational effectiveness of this and similar models, future studies should investigate additional aspects such as teachers' classroom behavior using classroom observational techniques and also techniques for the assessment of students' achievement and progress resulting from teachers' involvement in similar professional development activities. In order to get a better insight of school-based leadership, we recommend observing and analyzing the types of interactions and dynamics that exist among the teachers in the team and between the team and the teacher-leader.

In addition, since teacher-leaders do not work in isolation (Spillane, Halverson, & Diamond, 2001) but rather, in a complex system, in a research study one must also consider variables that can enhance or inhibit the implementation of such and similar reforms. Among these are the centralized system that limits the teachers' flexibility, and traditional assessment methods that inhibit the implementation of instructional techniques.

Summary and Concluding Remarks

A long term and intensive program was provided for 19 chemistry teachers in Israel. The main goal of the program was to develop teacher leaders that will support and help to attain goals of reform that is taking place in Israel. The reform in chemistry education in Israel is characterized both in the content of chemistry as well as in the pedagogy of chemistry namely in the instructional techniques and learning methods implemented in the chemistry classroom in order to make the classroom learning environment more educationally effective. The model that was adopted for this study was the one developed by Gilbert and Bell (1994; Bell 1998) in New Zealand. They suggested that science teacher development is viewed as professional, social, and personal development and that teacher development programs and activities should address these three interrelated components. The professional development program described in details in this paper was developed with the goal in mind that change in these three aspects will occur. The results of the assessment of the teachers' development throughout the program provided some evidence that the experiences and content provided for the chemistry teachers through the various professional development strategies used in the program aiming at enhancing the teachers', '*content knowledge', 'pedagogical content knowledge',* and leadership skills were effective in the development of the teachers in this three professional domains. In regard to teachers' development at the *personal* level we presented evidence (from both the quantitative sources as well as from the qualitative sources) that as a result of their experiences, the teachers developed affectively. This development involves attending to feelings about the change process they underwent, about their feelings regarding change they underwent as chemistry teachers, and finally the increased confidence (over time) regarding the idea that they might become leaders in chemistry education. *Professional* development relates mainly to the teachers development in the content of the subject matter they teach and to the relevant pedagogical content knowledge. Evidence on this component were gathered from students perceptions of the chemistry classroom learning environment as well as from the teachers self-reports regarding changes they underwent which they applied in their practice in their classroom in their own schools, and in out-of-school activities namely in the science teachers' professional development centers. Finally, the teachers had many opportunities to enhance their *social* skills through collaborations and cooperation with their peers in the program, through working with the team of chemistry teachers in their own schools, and in a later stage in the professional development activities as tutors in professional development programs. Evidence for the development of this the social component were obtained from the self-report questionnaire (feedback questionnaire) from interviews and the unobtrusive observations conducted by the tutors and researchers involved in the leadership program.

In conclusion it is suggested, that this study provides information regarding the validity of the Gilbret and Bell's (1994) model for the professional development of chemistry teachers in general and chemistry teacher-leaders in particular.

Until the '90s most of the efforts in trying to achieve the desired changes in school science focused on the development of improved science curricula. In the last decade, however, more attention has been gradually given to the teacher, since past efforts in educational reform suggested that the teacher plays a critical role in the ways new ideas are created in the classroom. Thus, it was realized that the teachers' need to learn to teach in new ways should not be ignored. Consequently, changing the in-service work with teachers was required. The establishment of regional teacher centers created a comprehensive framework that can provide opportunities for in-service teachers for life-long learning in their profession. Achieving scientific literacy for all has become a national goal for education in many countries. Although admirable, this goal represents a challenge for science teachers and for those responsible for professional development. Achieving this goal must be accompanied by a reform in the way science is taught in schools and in the methods that are used to make science teachers more professional in general and by the development of leadership among science teachers in particular.

Unfortunately, the literature regarding the development of leadership in the context of science education is rather scarce. We sincerely hope that this article will contribute to future developments in this area and will open a window for new developments and progress.

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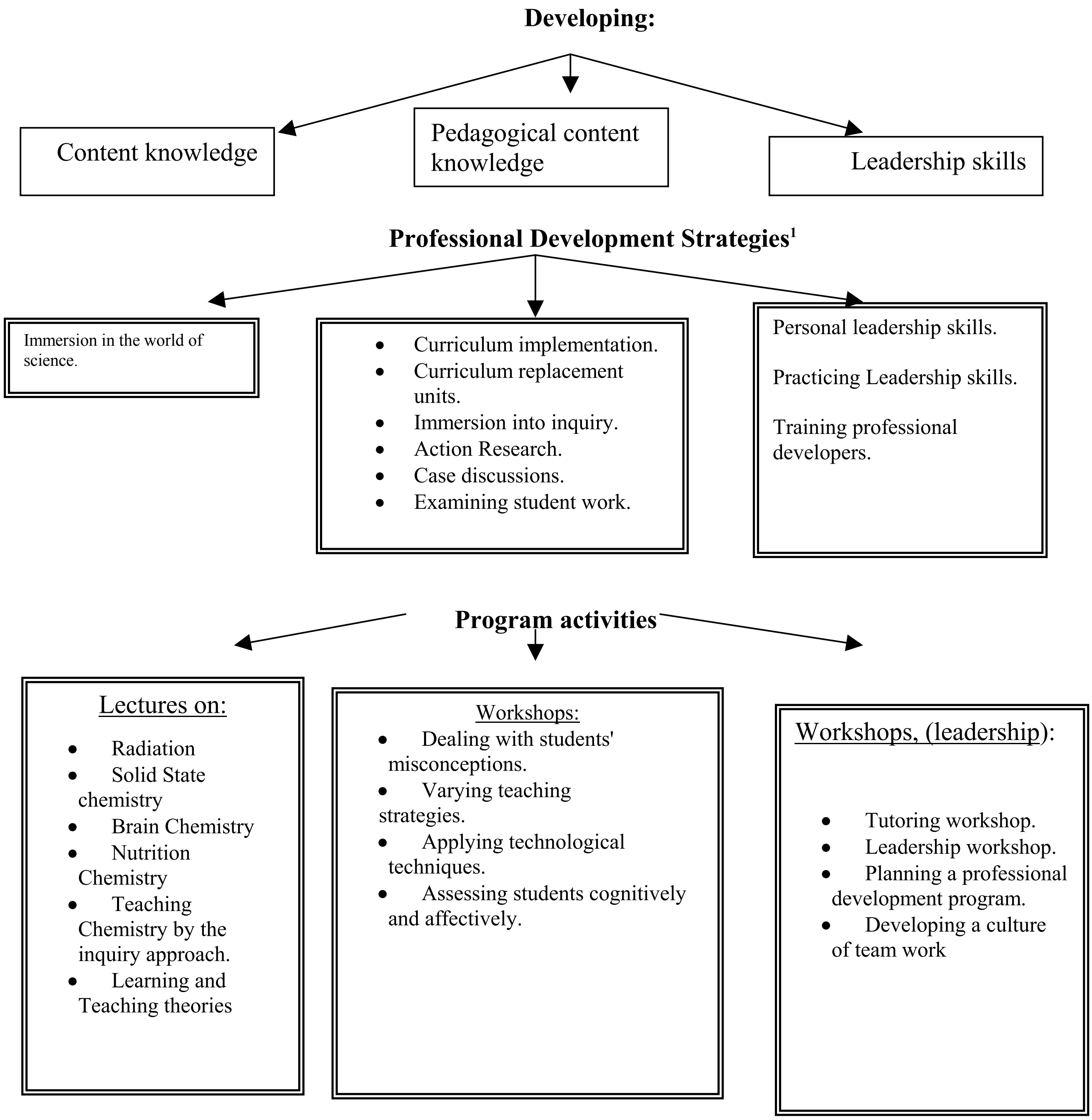
Figure 1: Structure of the Program



[1] Based on Loucks-Horsley et al. (1998)

Table 1: The feedback Questionnaire

No.	Items	End of 1st year N=14 Mean (S.D)	End of 2nd year N=14 Mean (S.D)	F value	Category Gilbert & Bell (1994)
1	I collaborated extensively with my colleagues in order to benefit from this program.	6.38 (0.35)	6.54 (0.54)	N.S.	Social
2	I am glad I had many opportunities to share mutual problems with my colleagues.	6.38 (0.76)	6.77 (0.43)	N.S.	Social
3	I am interested in initiating activities for my chemistry team in school.	6.17 (1.19)	6.25 (0.93)	N.S.	Social
4	I feel that I can promote chemistry education in my school.	6.00 (0.91)	6.23 (0.72)	N.S.	Personal
5	I received many tools to improve chemistry teaching.	5.77 (0.73)	6.38 (0.51)	F=2.89 P<0.05	Professional
6	I feel that I acquired new knowledge in the field of science teaching..	5.62 (0.77)	6.31 (0.63)	F=2.92 P<0.05	Professional
7	During the program I shared a lot of knowledge with my colleagues.	5.41 (1.51)	6.08 (0.67)	N.S.	Social
8	I feel that the program helped me enhance interest in chemistry in many of my students.	5.00 (1.41)	5.73 (1.49)	N.S.	Professional
9	The program gave me tools to cope with my students' learning difficulties.	4.77 (1.30)	6.00 (1.00)	F=3.25 P<0.01	Professional
10	I feel that the program made me a more professional teacher.	4.75 (1.36)	6.08 (0.90)	F=3.37 P<0.01	Personal
11	Most of my expectations from the program were fulfilled.	4.69 (1.36)	5.77 (0.83)	F=3.27 P<0.01	Personal
12*	I feel there is no remarkable change in the way I teach chemistry.	3.75 (1.15)	2.42 (1.41)	F=4.00 P<0.005	Personal

* Negative item

Table 2: Scales, sample items and reliability coefficient for the LEI

Scale	Explanation of the aspect examined and a sample item *(in italics)*	α-Cronbach Reliability Coefficient
Diversity	To what extent is there a wide variety of interests of the students *"In class, there are students with wide ranges of interest"*.	0.64
Speed*	Describe the speed of progress in class: *"The speed of progress in chemistry lessons is quite quick*".	0.66
Friction*	There is tension and friction between students: "*There is sensitivity in class that causes a separation between the students"*.	0.79
Favoritism*	There is a preference of certain students over others: *"The best students receive special attention"*.	0.80
Satisfaction	There is pleasure and satisfaction from the chemistry lessons: "*The students are looking forward to the chemistry lessons.*	0.65
Difficulty*	Demonstrate to what extent they think that the studies are difficult and complicated: *"Many students in the class have problems in carrying out the work in chemistry lessons"*.	0.60
Goal direction	To what extent are the objectives of studying chemistry clear: *"It is clear to all of the students in class what the objectives of the subject are"*.	0.67

Table 3- Analysis of variance for the LEI scales

Scale	1997 N=196 Mean (SD)	1998 N=183 Mean (SD)	F-value And Significance level
Diversity	2.92	2.99	F=3.39
	(0.41)	(0.40)	P<0.05
Speed*	2.62	2.42	F=21.31
	(0.41	(0.41)	P<0.001
Friction*	2.30	1.99	F=28.75
	(0.60)	(0.50)	P<0.001
Favoritism*	1.95	1.80	F=8.28
	(0.52)	(0.54)	P<0.005
Satisfaction	2.57	2.70	F=10.41
	(0.42)	(0.41)	P<0.005
Difficulty*	2.56	2.48	N.S
	(0.39)	(0.37)	
Goal Direction	2.89	2.97	F=3.91
	(0.43)	(0.40)	P<0.05

*** Negative scale**